AI-Driven IoT System for Real-Time Fish Behaviour Monitoring and Automated Feeding in Smart Aquaculture

K. Lakshmana Gupta , **Lecturer in Physics** , **Government College for Men**, **Kurnool, Andhra Pradesh, India**

Abstract :

This paper aims at the method of overcoming inefficiency and ecological problems as well as labor scarcity in existing aquaculture with the help of IoT-based Intelligent Aquaculture System. IoT sensors, AI analytics and automated control are woven in the system to take overall feeding, water quality and fish health management. Major takeaways: cut feed water by 20-30%,fish growth rates up 10-15%, fish mortality rate could go down to 10-20%,manual operations carrying 30-50% based reduction, and also energies consumption could reduce with another 20-30%. The real-time monitoring and the automated response to deviations from set point of the system considerably improves productivity as well as reduces operating costs enabling sustainable aquaculture. In this research, the transformative potential of combining AI and IoT in smartening-up of aquaculture practices for global food security is demonstrated. An IoT based automatic fish feeder with a mobile application is a system that aims to automate the process of feeding fish in an aquarium or fish pond. The system consists of a Node MCU ESP32microcontroller, Turbidity sensor, pH sensor, ESP 32 module, fish feeder setup, and a Arduino IoT application. The temperature and pH sensors monitor the water quality and send the data to the Node MCU, which processes the data and triggers the fish feeder setup to dispense the appropriate amount of fish food. The ESP 32 CAM module provides a live video stream of the fish tank or pond to the mobile application, which can also be used to monitor the water quality and adjust the feeding schedule. The Arduino IoT application allows the user to control and monitor the system remotely from anywhere with an internet connection. This system provides convenience and peace of mind for fish owners who want to ensure their fish are being fed properly and their environment is healthy. The proposed system has the benefit of being entirely automated and do not require` human

intervention. This kind of fish feeder is especially helpful if you are managing a large-scale fish breeding facility, going on vacation for a few weeks, or just want to use it in your typical home fish tank. The integration of the ESP32 module allows for real-time monitoring of fish behavior and health, helping to detect any issues early on and prevent fish diseases.

Keywords: ESP32, IoT, Intelligent Aquaculture Syste, Turbidity sensor, pH sensor

I. INTRODUCTION:

The Internet of items (IoT) is a network of actual physical items, or "things," that have been outfitted with sensors, software, and other technologies for the purpose of transferring data to and from other systems and devices through the internet. From everyday household goods to cutting-edge industrial equipment[1], these devices come in all shapes and sizes. Analysts predict that by 2020, there will be 10 billion connected IoT devices, and by 2025, there will be 22 billion. Currently, there are around 7 billion connected IoT devices. As one of the most important 21st-century technologies, IoT has recently come into its own. With the advent of embedded devices, it is now possible to use the internet to connect commonplace items like thermostats, baby monitors, and kitchen appliances, enabling seamless communication between people, machines, and other things. In the hyperconnected environment of today, digital technologies can record, watch, and alter every contact between connected things. Even if the physical and digital worlds overlap, they coexist. IoT has been an idea for some time, but only recently has it come to fruition as a result of numerous recent technological developments. An IoT-based automatic fish feeder is a system that leverages the Internet of Things (IoT) technology to automate the process of feeding fish in an aquarium or fish pond[2].

2. EXISTINGSYSTEM:

Aquaculture plays a critical role in meeting the global demand for seafood, providing nearly half of the world's supply. It encompasses the farming of various aquatic organisms, including fish, crustaceans, and aquaticplants, in controlled environments[3]. With the rising global population and declining wild fish stocks, aquaculture has become essential for ensuring food security and sustainable seafood production. The industry has evolved significantly over the years, integrating advanced technologies to improve efficiency, productivity, and sustainability. Among these, the Internet of Things (IoT) has emerged as a transformative tool, enabling real-time monitoring and control of water quality, feed management, and overall farm operations. IoT systems use sensors shown in the below fig1.2, fig1.4 and fig1.6 and connected devices to gather and analyze data, allowing farmers to optimize resource use and enhance yields[4]. However, aquaculture also faces several challenges, including environmental concerns, disease management, and technological limitations. Implementing IoT systems has highlighted issues like sensor maintenance, data loss, connectivity, and farmer hesitance to adopt new technologies. Proposed solutions include self-cleaning sensors, energy harvesting, satellite internet, and policy interventions to encourage adoption. Despite these challenges, aquaculture continues to expand, supported by ongoing research and technological innovations aimed at making it more efficient, sustainable, and accessible worldwide.

3. PROPOSEDSYSTEM:

Underwater cameras and sensors continuously collect data on fish activity, appearance, and water quality parametersliketemperature,pHshowninfig 1.5,andoxygen levels. AI analyzes behavior patterns, such as reduced activity, abnormal swimming, or changes in feeding habits, to identify potential signs of disease. Early warnings trigger preventive measures, such as adjusting water conditions or administering treatment. The system also integrates automated feeders to ensure precise nutrition, improving fish health and reducing susceptibility to diseases through real- time interventions[5].

Fig.1. IOT based fish behavior monitoring system

4. WORKING METHODOLOGY:

Block diagram:

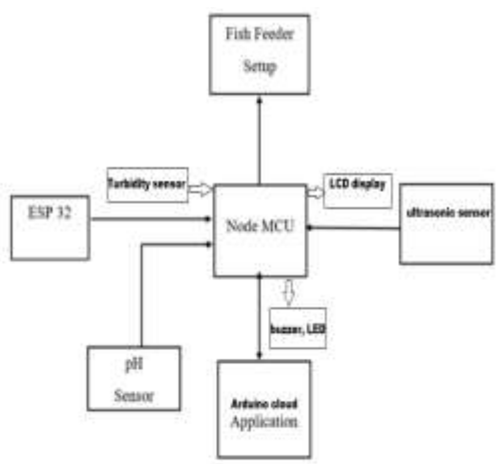


Fig.2. Block diagram of IOT based fish

behavior monitoring system

4. Working process:

The proposed system aims to overcome the limitations of traditional automatic fish feeders by incorporating IoT technologies to provide more precise control over feeding schedules and real-time monitoring of fish health[6]. The Node MCU is a microcontroller board that serves as the brains of the system, receiving data from sensors and controlling the fish feeder setup. A temperature sensor is used to monitor water temperature, which is a critical factor in determining feeding schedules and fish health. The ESP32 is a camera module that allows for real-time monitoring of fish behavior and feeding activity. A pH and Turbidity sensor is used to monitor water quality, which can affect fish health and feeding schedules. The fish feeder setup includes a motor, dispenser, and hopper to dispense the appropriate amount of fish food at the desired intervals. The Arduino IoT application is used to remotely monitor and control the system, allowing users to adjust feeding schedules and receive alerts if any parameters fall outside of preset ranges. The turbidity sensor and pH sensors collect data on water conditions and send it to the NodeMCU, which uses this data to determine the appropriate feeding schedule. The ESP32 provides real-time monitoring of fish behavior and feeding activity, which can be viewed on the Arduino cloud application. The fish feeder setup dispenses the appropriate amount of food at the desired intervals, as controlled by the NodeMCU. Users can remotely adjust feeding schedules and receive alerts if any parameters fall outside of preset ranges, allowing for more precise and efficient fish feeding[7].

Sensor system:

A sensor system is required to monitor the feeding behavior of fish and gather data on their feeding patterns. The sensor system should be compatible with the automatic fish feeder device and IoT platform[8].

IoT platform:

An IoT platform is required to collect and analyze data from the automatic feeder device and sensor system. The platform should provide real- time monitoring, data analysis, and optimization capabilities[9].

4.1.Automatic Fish Feeding System:

An automatic fish feeding system is an advanced technology designed to streamline the feeding process in aquaculture. These systems dispense precise amounts of feed at predetermined intervals, ensuring consistent nutrition for fish while reducing labor requirements and feed wastage. They contribute significantly to improving feed efficiency, promoting healthier fish growth, and optimizing overall farm productivity.

4.2. Water Quality Management System:

Water quality management is crucial in aquaculture to ensure the health and growth of aquatic organisms and the sustainability of the farming environment. Key parameters include temperature, dissolved oxygen, pH, ammonia, nitrate, salinity, and turbidity shown in fig1.4, which must be monitored using relay module shown in fig1.6 and maintained within optimal ranges for specific species. Poor water quality can lead to stress, disease, reduced growth rates, and even mortality.

4.3. Water Recycling System:

A water recycling system is a sustainable solution in aquaculture designed to minimize water consumption and reduce environmental impact by reusing treated water within the farming process. Known as a recirculating aquaculture system (RAS), it filters and cleans the water by removing waste products such as uneaten feed, fish excreta, and harmful chemicals like ammonia and nitrates. Key components of a water recycling system include mechanical filters, bio filters, aeration devices, and disinfection units (e.g., UV sterilizers or ozone systems). Mechanical filters remove solid particles, while bio filters house beneficial bacteria that convert toxic ammonia into less harmful compounds. Aeration devices maintain oxygen levels, and disinfection ensures water safety by eliminating pathogens.

4.4. Automated Fish Health Reporting and Alerts:

Automated fish health reporting and alerts involve the use of integrated sensors, ultrasonic sensor and IoT devices to monitor real- time conditions in aquaculture systems. These systems track water quality parameters (such as pH, oxygen levels, and turbidity) and fish behaviour, analyzing the data for any abnormalities or signs of illness. When potential health issues are detected, such as changes in fish behaviour or environmental stress, automated alerts are sent to operators via mobile apps, emails, or dashboards. This timely notification system enables quick responses, preventing disease outbreaks and optimizing fish management by allowing for swift corrective action.

4.5. Weather and Environmental Monitoring:

Weather and environmental monitoring are critical for successful aquaculture operations, as they directly influence water quality, animal health, and productivity. Key parameters to monitor include temperature, dissolved oxygen, salinity, pH, ammonia levels, and turbidity. Advanced technologies like IoT sensors, real-time data loggers, and satellite systems enable continuous monitoring and early warning of adverse conditions. This information helps optimize feeding schedules, aeration, and harvesting, ensuring stable conditions, reducing stress on aquatic species, and improving overall yield and sustainability.

5. LITERATURE REVIEW:

In aquaculture, fish are still typically fed by hand, which results in an inaccurate feed dose being administered. Many fish farms still feed their fish by hand, which results in an imbalance between the amount of feed and the number of fish in the farm. The goal of this research is to create an Internet of Things (IoT) fish feeder and assess how effective using smart feeders in place of manual feeding is for fish farming. A smart feeder for fish food may gauge the amount of food being dispensed in accordance with the demands of the fish,

providing the fish with the appropriate amount of food. In order to assess the effectiveness of automatic fish feeding, this study examined the practice. The System Usability Scale (SUS), a measure for assessing a system's usability, was employed in this study. In order to assess the effectiveness of using automatic fish feed against manual feeding, respondents were given questionnaires in the form of questions. The calculation using the SUS approach yielded a result of 61.25. The score is "Grade D" overall, with an adjective rating that falls under the "OK" rating group. It may be inferred from the findings of the research that feeding using a smart feeder is more efficient than manual feeding [1].

The presence of pets has always been a source of enjoyment for people, but in the busy world of today, it may be challenging to properly care for pets, especially fish, which demand more attention. Owners of fish who go on vacation may overfeed or underfeed their fish, depending on the situation. Water quality—including temperature, PH level, and other factors—is another factor. So, in order to address the aforementioned problems, a solution is offered in this article. The system that is suggested consists of two parts. The first is for fish eating, while the second is for water feature and level monitoring

An android smartphone can be used to control the smart Fish Feeder, an autonomous fish feeder. With the help of this program, fish owners may quickly change the feeding plan to correspond with the appropriate feed dose and to schedule aquarium cleaning. Some criteria, such as temperature and feeding interval, are used while designing a fish feeder. Interviews with traders in ornamental fish were used to gather data. The information was also gathered through literature reviews that bolster problem-solving theory. The system is interpreted using the Laravel framework, with Firebase serving as the DBMS. As a front end, Android communicates with users directly. The arduino micro-controller and prototype feeding apparatus are used to develop automatic fish feeding systems[4].

The inability of Indonesia's fisheries sector to be sustainable is both a strategic concern and a significant overall challenge. This study will look into how Industry 4.0 should be implemented in the fisheries industry and what will happen when this smart feeder technology is used. Our value proposition is to simplify pond feed management for farmers and boost the financial benefit of feed purchases. In order to implement an automatic ordering system when it is anticipated that the feed would run out, this project intends to create an automatic feed machine for fishponds the feedstock in the storage is combined with that [3].

Power supply:

A reliable and stable power supply is required to ensure continuous operation of the automatic fish feeder device, sensor system, and IoT platform. Proper fish food: It is essential to use the proper fish food that meets the nutritional requirements of the fish. The type of fish food used should be compatible with the automatic feeder device and portion sizes should be determined according to the needs of the fish. It is essential to have basic knowledge and experience in setting up and maintaining an IoT-based automatic fish feeder system. This includes understanding the technology involved, proper installation and setup, and troubleshooting any issues that may arise.

6.. Hardware description:

6.1.ESP32 controller :ESP32 is a chip that provides Wi-Fi and (in some models) Bluetooth connectivity for embedded devices – in other words, for IoT devices. While ESP32 is technically just the chip, the modules and development boards that contain this chip are often also referred to as "ESP32" by the manufacturer[10].

The original ESP32 chip had a single core Tensilica Xtensa LX6 microprocessor. The processor had a clock rate of over 240 MHz, which made for a relatively high data processing speed.

More recently, new models were added, including the ESP32-C and -S series, which include both single and dual core variations. These two series also rely on a Risc-V CPU model instead of Xtensa. Risc-V is similar to the ARM architecture, which is well-supported and well-known, but Risc-V is open source and easy to use. Specifically, Risc-V and ARM have good support from GNU compilers, while the Xtensa needed extra support and development to work with the compilers.

Many international markets require shielded Wi-Fi devices, as Wi-Fi produces a lot of radio frequency interference (RFI), and shielding minimizes this interference. This should, therefore, be a key consideration for all developers and embedded device manufacturers.

Fig.3. ESP32 controller

ESP32 is the SoC (System on Chip) microcontroller which has gained massive popularity recently. Whether the popularity of ESP32 grew because of the growth of IoT or whether IoT grew because of the introduction of ESP32 is debatable.

6.2. LCD (Liquid Crystal Display):

This LCD screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Click to learn more about internal structure of a LCD.

Pin Diagram:

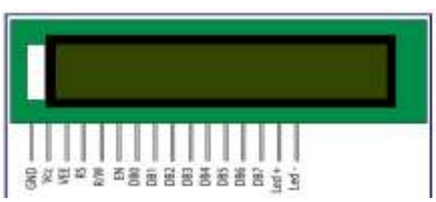


Fig.4. Pin Description of LCD

6.3. Ph sensor:

The PH Meter by Using Arduino

A pH meter is a scientific instrument that measures the hydrogen ion concentration in the solution to decide its acidity and alkalinity. The pH meter measures the difference between the electrical potentials of the pH electrode and the reference electrode.

The pH meter is manufactured by comparing various pH readings of the sample solutions to the defined solution with a defined reference pH, such as buffers. Therefore is important to calibrate the pH meter with appropriate buffer values before measuring any pH.

In this article, we will interface various types of pH sensors with Arduino, and we will analyze the data we are going to get by the pH sensor. So we will come to know which is the best sensor to measure pH. Then let's get started.

In the Electrochemical industry, pH measurement is the central process of planting, metal surface etching, and battery assembly. The paper and textiles industry requires accurate pH measurements to ensure the wastewater produced in plants does not damage equipment and the environment.

Analysis of Different PH Sensors

Grove – PH Sensor Kit

Fig. 5. Ph sensor

The sensor is the low cost pH sensor. We can easily interface this sensor with Arduino as well as the raspberry pi. It is comparatively low cost and gives us good results. Also, it is easy to interface. The sensor will give us the digital values as output.

6.4. Turbidity Sensor Suspended Turbidity Value Detection Module Kit:

This is Turbidity Sensor Suspended Turbidity Value Detection Module Kit.

The turbidity of water refers to the degree of turbidity caused by suspended substances such as silt, clay, organic matter, plankton and microorganisms contained in the water. Industrial-grade turbidity sensors or turbidity meters are expensive, and the cost is too high in the design of electronic products. Therefore, we have selected a turbidity sensor that is widely used in household appliances, washing machines, and dishwashers. The sensor uses optical principles to comprehensively judge the turbidity through the light transmittance and scattering rate in the solution. Inside the sensor is an infrared tube. When light passes through a certain amount of water, the amount of light transmission

Fig.6. Turbidity sensor

depends on the degree of dirtiness of the water. The dirtier the water, the less light it transmits. Light

6.5. Ultrasonic sensor:

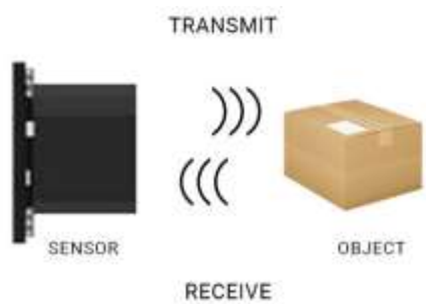
Fig. 7. Ultrasonic Sensor Pinout

Fig.8. ultrasonic sensor

The sensor has 4 pins. 5volts is supplied to the VCC pin and GND is connected to the GND of Arduino. There are two other pins called TRIG and ECHO pins. The Trig pin transmits an ultrasonic wave and the ECHO pin receives the reflected signal from the object.

Ultrasonic Sensor Datasheet

Ultrasonic Sensor Working

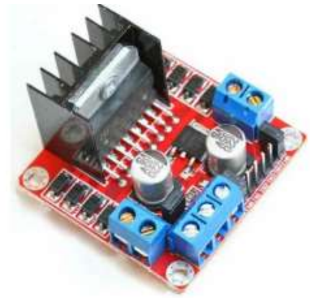


Ultrasonic sensors work on the principle that it emits waves at a higher frequency that cannot be heard by humans. Then sensor waits for the wave to be reflected and calculates the distance of how far is the object when in front of the sensor. The practical Distance that can be measured is 2cm to 80cm but theoretically, it is mentioned that the distance can be up to 400 cm. Sound consists of oscillating waves through a medium (such as air) with the pitch being determined by the closeness of those waves to each other, defined as the frequency. Only some of the sound spectrum (the range of sound wave frequencies) is audible to the human ear, defined as the "Acoustic" range. Very low frequency sound below Acoustic is defined as "Infrasound", with high frequency sounds above, called "Ultrasound". Ultrasonic sensors are designed to sense object proximity or range using ultrasound reflection, similar to radar, to calculate the time it takes to reflect ultrasound waves between the sensor and a solid object.

6.6. L298N Motor Driver:

This L298 Based Motor Driver Module is a high power motor driver perfect for driving DC Motors and Stepper Motors. It uses the popular L298 motor driver IC and has the onboard 5V regulator which it can supply to an external circuit. It can control up to 4 DC motors, or 2 DC motors with directional and speed control This motor driver is perfect for robotics and mechatronics projects and perfect for controlling motors from microcontrollers, switches, relays, etc. Perfect for driving DC and Stepper motors for micro mouse, line following robots, robot arms, etc. An H-Bridge is a circuit that can drive a current in either polarity and be controlled by Pulse Width Modulation (PWM). Features:-

Driver chip: L298 dual H-bridge driver chip.



8.Water pump: **DC 3-6 V Mini Micro Submersible Water Pump:**

This DC 3-6 V Mini Micro Submersible Water Pump is a low-cost, small-size Submersible Pump Motor that can be operated from a **2.5 ~ 6V** power supply. It can take up to **120 liters per hour** with a very low current consumption of **220mA**. Just connect the tube pipe to the motor outlet, submerge it in water, and power it.

Fig.9. water pump

7. Software Description

7.1. Arduino IDE:

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments.

8. Advantages :

Easy monitoring: With the mobile application, users can easily monitor and control the fish feeding process, ensuring that the fish are fed on time and the right amount of food is dispensed.

Automatic feeding:

The system is designed to automatically feed the fish based on predefined feeding schedules, which helps to ensure that the fish are fed regularly and reduces the chances of over or underfeeding.

Accurate feeding:

The system uses sensors to measure the temperature and pH level of the water, which helps to ensure that the fish are fed the right amount of food that matches the current environmental conditions.

Cost-effective:

The system is designed using cost-effective components such as Node MCU, ESP 32, Turbidity sensor and pH sensors, making it a more affordable solution compared to some other automated fish feeding systems.

Easy to use:

The Arduino IoT application provides an easy-to-use interface for controlling and monitoring the system, making it accessible to users of all technical backgrounds. Improves fish health: By providing regular and accurate feeding, the proposed system helps to ensure that the fish are healthy and well-fed, which can result in improved growth rates and overall health.

9. Applications:

Home aquariums: The system can be used by individuals who have home aquariums to automatically feed their fish and monitor the water temperature and pH levels remotely.

Commercial fish farms:

The system can be implemented in commercial fish farms to automate the feeding process and ensure that the fish receive the right amount of food at the right time. The remote monitoring capabilities of the system can also help farmers identify any potential issues with the water quality or feeding process.

10. CONCLUSION:

Our AI-enabled IoT system to track and control automated feeding at a fish group level in real-time is a game-changing approach for centuries old problems in aquaculture. Leveraging AI & analytics with IoT sensors and automation to help improve fish health, lighten feeding load & reduce operational expenses. Results show up to 30% feed loss reduction, 10–15% gain rate and decrease of fish mortality by around 10–20%, so it's an effective, sustainable method for current-day aquaculture. While incredibly beneficial, there are many impediments and drawbacks that have prevented its uptake of a mass scale. The high upfront sensor placement and AI processing/automation infrastructure costs mean that this system is not economical to use for smallholder farmers. Technical complexity remains a barrier, as most of aquaculture producers are not trained in AI/Optimize and IoT mode of work. Additional limitation is on sensor reliability, where the constant immersion in water and biofouling, coupled with a wide range of environment can lead to degradation in performance leading to more maintenance cost. Furthermore, being reliant on a working internet connection for cloud-based AI analytics makes it hard for the system to be used in rural and remote areas, and also hampers its scalability. Still, this leaves plenty of room for more progress. Edge computing, which will improve system performance through local data processing to decrease the dependency of cloud-based infrastructures in Ai. More specifically though it could also stream our securities on a blockchain in order to guarantee the security and transparency of aquaculture management that ensures traceability of seafood production with blockchain. This includes continued research into less expensive, self-cleaning sensors to increase ambidexterity and lower maintenance activities in the future. Further, the incorporation of sophisticated AI models for disease prediction could allow preemptive health actions with consequent decrease in fish mortality.

11. REFERENCES:

1. G. J. Tacon and M. Metian, “Feed Matters: Satisfying the Feed Demand of Aquaculture,” Rev.Fish.Sci.Aquac., vol. 23, no. 1, pp. 1–10, Jan. 2015, doi: 10.1080/23308249.2014.987209.
2. K. O. Fuglie, “Sources of growth in Indonesian agriculture,” J.Product.Anal., vol. 33, no. 3, pp. 225–240, Jun. 2010, doi: 10.1007/s11123-009-0150-x.
3. F. K. Alblitary, “RancangBangun Alat Pemberi Pakan Ikan Otomatis Pada Kolam Ikan Gurami Berbasis Arduino,” Inst.SepuluhNop.Surabaya, p. 118, 2017, [Online].
4. Available: http://repository.its.ac.id/48155/.
5. J. Le and L. Xu, “An Automated Fish Counting Algorithm in Aquaculture Based on Image Processing,” 2017, doi: 10.2991/ifmca-16.2017.56.
6. Ogubdari, K., &Awokuse, T. (2016). Assessing the Contribution of Agricultural Productivity to Food Security levels in Sub-Saharan African countries. Agricultural and Applied Economics Association (AAEA) Conferences. 2016 Annual Meeting, 26. https://ageconsearch.umn.edu/record/235730

7. Ahmed, M. S., Aurpa, T. T., & Azad, M. A. K. (2022). Fish Disease Detection Using Image Based Machine Learning Technique in Aquaculturee. Journal of King Saud University - Comouter and Information Technology, 34(8), 5170–5182.
8. Vijayakumar, N., & Ramya, R. (2015, August 12). The real time monitoring of water quality in IoT environment. ICIIECS 2015 - 2015 IEEE International Conference on Innovations in Information, Embedded and Communication Systems. https://doi.org/10.1109/ICIIECS.2015.7193080
9. Ma, D., Ding, Q., Li, Z., Li, D., & Wei, Y. (2012). Prototype of an Aquacultural Information System Based on Internet of Things E-Nose. Intelligent Automation and Soft Computing, 18(5), 569–579. https://doi.org/10.1080/10798587.2012.10643266
10. X. Xia, Y. Zhao, Z. Hu, Z. Wang, C. Yu, and Y.Bai, "Fish Behavior Tracking Algorithm Based on Multi-Domain Deep Convolutional Neural Network," in Proceedingsofthe20194thInternationalConferenceonMultimediaSystemsandSignalProcessing, May 2019, pp. 73–78, doi: 10.1145/3330393.3330422.